Influence of type and amount of lignin on decay by *Coriolus versicolor*[1]

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Samples of a hardwood containing primarily coniferous (guaiacyl) lignin and hardwoods and softwoods with normal amounts of guaiacyl and syringyl lignin were degraded by the white-rot fungus *Coriolus versicolor* (L. ex Fr.) to assess the influence of type and amount of lignin on rate of decay. Lignin and carbohydrate losses were compared for the woods at various degrees of weight loss. The hardwood with coniferous lignin was degraded in a manner similar to the softwoods, indicating that the type of lignin is more a factor in the slower rate of *C. versicolor* decay of softwoods than is the amount of lignin, or the anatomical structure itself.

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Pour évaluer l'influence de la sorte et de la quantité de lignine sur le progrès de la carie, on a soumis, à la détérioration par le champignon de carie blanche *Coriolus versicolor* (L. ex Fr.), des échantillons d'un feuillu constitué surtout de lignine conifériennc (guaiacyl) et de feuillus et de conifères à quantités normales de lignine guaiacyl et de lignine syringyl. Les pertes de lignine et d'hydrates de carbone furent comparées chez ces bois à divers niveaux de perte de poids. Le feuillu à lignine coniférienne s'est détérioré de même façon que les conifères, ce qui indique que la sorte de lignine constitue un facteur plus important dans la carie plus lente du *C. versicolor* chez les conifères que la quantité de lignine ou que la structure anatomique elle-même.

[Traduit par le journal]

Introduction

Previous studies have failed to indicate that the slower rate of degradation often observed in softwood species in service by white-rot fungi is not due to (*a*) preferential formation of cellulases and hemicellulases on hardwood substrates (Highley 1973, 1976), (*b*) retarded ingress of mycelium via pits in softwood cells because of pit aspiration (Highley 1978), or (*c*) inhibitory extractives in softwoods (Peterson and Cowling 1964; Thompson 1965). Other studies have proposed that inadequate moisture in wood possibly accounts for the slow rate of decay by white-rot fungi in softwoods (Highley 1978; Highley and Scheffer 1970; Peterson and Cowling 1973).

Differences in the nature and content of lignin in hardwoods and softwoods must also be considered (Peterson and Cowling 1964; Takahashi 1978). White-rot fungi must degrade lignin to gain access to the polysaccharides. The slower decay of softwoods by certain white-rot fungi has been attributed (Bailey *et al.* 1968; Peterson and Cowling 1964; Takahashi 1976) to their higher lignin content. The chemical nature of softwood lignin, too, differs from that of hardwoods. Hardwood lignin contains both guaiacyl and syringyl residues, but softwoods contain only guaiacyl residues.

Kirk *et al.* (1975) found that, in the degradation of birchwood, *Coriolus versicolor* (L. ex Fr.) degrades syringyl-rich lignin first and then guaiacyl-rich lignin. They attributed the preferential attack to the microstructural distribution of the two types of lignin. Their work does, however, raise the possibility that successive degradation of the different lignin residues may be related to the preferential attack of hardwoods by white-rot fungi.

Ceibo wood (*Erythrina crista-galli* L.) is an atypical hardwood in that it contains primarily coniferous lignin, i.e., guaiacyl residues (Kawamura *et al.* 1975), and its lignin content is high (Klason lignin = 31.4%). Its other chemical and morphological properties are comparable to typical hardwoods. To shed further light on the role of lignin in decay of wood by white-rot fungi, decay of this peculiar hardwood by the white-rot fungus, *C. versicolor*, was compared with decay of more typical hardwoods and softwoods.

Method

Blocks, 0.5 by 0.5 by 0.125 in. (1 in. = 2.54 cm), the small dimension in the grain direction, were cut from Ceibo (*E. crista-galli*) and sapwood of sweetgum (*Liquidambar styraciflua* L.), white oak (*Quercus alba* L.), white spruce (*Picea glauca* (Moench.) Voss.), southern pine (*Pinus* sp.), and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). Lignin and carbohydrate contents were determined on the sound wood (Table 1). The blocks were extracted in ethanol–

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TABLE 1. Analysis of sound wood

Species	Lignin content (%)	Carbohydrate content (%)
Hardwoods		
Sweetgum	20.1	67.8
White oak	27.1	62.2
Ceibo	31.4	65.1
Softwoods		
Western hemlock	30.6	65.2
White spruce	27.0	67.8
Southern pine	28.0	64.4

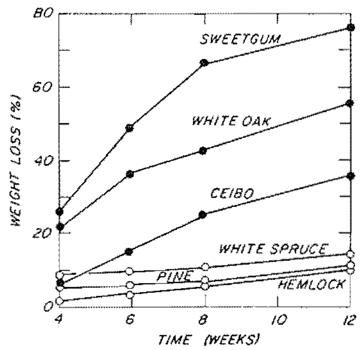

FIG. 1. Weight loss caused by *Coriolus versicolor* in hardwoods and softwoods.

benzene (Anonymous 1956*b*), followed by hot water extraction (Anonymous 1956*a*). They were decayed by *C. versicolor* (L. ex Fr.) (Mad. 697) in soil-block chambers for various time periods to obtain a range of weight losses (Anonymous 1971). Eight replicates per species were removed and weighed at each time interval. Percentage weight loss, the measure of decay, was calculated from the weights of the decayed blocks after they were brought to equilibrium at 70% relative humidity and 27°C. Noninoculated blocks served as control.

Decayed blocks were ground to pass a 40-mesh screen and the wood meal was dried in a vacuum oven at 45°C. The wood meals were analyzed, without extraction, for sulfuric acid lignin and for total reducing sugars in acid hydrolysates (determined colorimetrically as glucose) (Moore and Johnson 1967).

Results and discussion

Figure 1 shows the weight losses caused by *C. versicolor* in the various types of woods at 4, 6, 8, and 12 weeks. The rate of degradation in gum sapwood (20.1% lignin) was greater than that in white oak sapwood (27.1% lignin). Because both of these woods contain typical hardwood lignin, the greater amount of lignin in white oak sapwood might have been a factor in its having been degraded more slowly. The white oak,

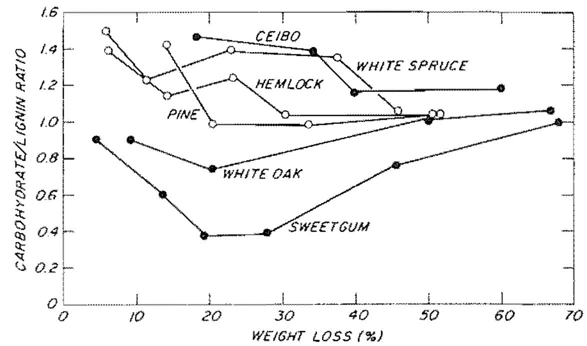

FIG. 2. Effect of wood species on removal of lignin and carbohydrate by *C. versicolor*.

however, was decayed at a substantially greater rate than Ceibo and the softwoods despite all having nearly equal amounts of lignin. At 4 weeks, weight loss by *C. versicolor* in Ceibo was similar to that of the softwoods. After 4 weeks, the decay rate in Ceibo accelerated considerably faster than in the softwoods but remained significantly less than in the two hardwoods with typical hardwood lignin. This indicates that structure of lignin may be more important than the amount of lignin as a factor in the slower degradation of softwoods by *C. versicolor*.

Studies in which small amounts of lignin have been removed from softwoods also indicate the amount of lignin in wood as not being solely responsible for the slower decay in softwoods by white-rot and soft-rot fungi (Bailey *et al.* 1968; Takahashi 1976, 1978). White rot or soft rot accelerated significantly with the removal of only small amounts of lignin. It has been proposed (Takahashi 1976, 1978) that the increased weight loss from white- or soft-rot attack may be due, in part, to structural changes in the cell wall (such as alteration of the structure of lignin or other cell constituents) caused by the delignification process.

The relative rates of degradation of the lignin and carbohydrates during decay (Table 2; Fig. 2) support this interpretation. In sweetgum, *C. versicolor* preferentially removed lignin, particularly at the lower weight losses. In white oak, lignin was also preferentially removed but the selectivity was not as great as in sweetgum. The carbohydrate/lignin (C/L) ratios produced by *C. versicolor* in Ceibo were similar to those of the softwoods, in that carbohydrate was preferred to lignin. At 10% loss in weight lignin loss was not detected in Ceibo whereas about 18% of the lignin in sweetgum was removed at this weight loss. Takahashi (1978) found that *C. versicolor* always simultaneously removed the major wood constituents in hardwoods, but that in softwoods a preferential degradation of nonlignin components sometimes occurred. Thus qualita-

TABLE 2. Loss of lignin and carbohydrate components in softwoods and hardwoods decayed by *Coriolus versicolor*

Species	Weight loss (%)	Loss of components		
		Lignin, % of original*	Carbohydrate, % of original	C/L ratio†
Hardwoods				
Sweetgum	5	4.5	4.0	0.89
	14	22.5	13.1	0.58
	18	41.3	15.4	0.37
	28	56.7	22.0	0.39
	46	58.9	43.5	0.74
	68	68.3	68.1	0.99
White oak	10	13.6	11.8	0.86
	21	29.0	20.9	0.72
	52	55.5	56.6	1.01
	66	66.2	72.0	1.08
Ceibo	8	0.0	13.0	—
	18	12.3	18.4	1.5
	35	27.1	36.2	1.3
	40	42.9	48.8	1.1
	60	55.8	65.9	1.2
Softwoods				
Western hemlock	7	9.1	12.6	1.4
	16	16.7	19.0	1.1
	24	22.8	27.9	1.2
	31	35.5	37.0	1.0
	50	49.8	51.6	1.0
White spruce	7	4.7	7.1	1.5
	12	11.1	13.6	1.2
	24	18.0	24.4	1.4
	38	33.4	44.2	1.3
	46	47.4	49.5	1.0
Southern pine	15	10.4	14.7	1.4
	21	19.6	18.8	0.96
	34	33.8	32.7	0.96
	51	19.6	18.8	1.0

*Percent of original component in sound wood (Table 1).
†Ratio of carbohydrate loss to lignin loss.

tive differences in the type of lignin apparently are a key factor in the slower degradation of woods with guaiacyl lignin by white-rot fungi such as *C. versicolor*.

An unknown factor, however, must also be involved in the greater resistance of softwoods to degradation by *C. versicolor* because the decay rate in the hardwood with predominantly guaiacyl lignin (Ceibo) accelerated considerably faster than in the softwoods after 4 weeks (Fig. 1). This unknown could be a difference between Ceibo and the softwoods in lignin distribution in the cell walls, hemicellulose composition, or anatomical differences.

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